HE Fragment Impact Modeling

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The impact and penetration of HE materials is a problem of considerable importance to the DOE and the DoD. LANL is studying ways to better quantify fragment impact by elucidating the underlying physics, and using fragment impact as a stringent test-bed to study the applicability of our HE models to correctly predict experimental outcomes, and develop solutions when deficiencies are found.

The response of a munition or a rocket propellant to a hostile fragment impact is known to be complex. A variety of results can occur: abrupt initiation, initiation after a slow buildup of chemical energy, or a weak chemical reaction that eventually extinguishes. Clearly the safety of nearby personnel, as well as system survivability, will depend on which scenario actually occurs. Studies at both the Department of Energy (DOE) and the Department of Defense (DoD) laboratories are underway to better quantify fragment impact. One approach at LANL is to design, build, and execute impact experiments that use simple geometries for the purpose of elucidating the underlying physics. Figure 1 shows one such design using a Taylor gun to propel a steel ball into a plated energetic material. On the other hand, DoD researchers at various laboratories around the country (Eglin Air Force Base, Picatinny Arsenal, Army Research Laboratory) are well suited to carry out fragment impact studies on full-up systems. They also use a variety of energetic material constitutive models to perform system-level simulations. Figure 2 shows an illustration of a DoD simulation using a LANL-developed high explosives (HE) model.

T-Division's interest in this problem lies in the fact that fragment impact provides a stringent test-bed to study the applicability of our HE models to the correct prediction of experimental outcomes. Moreover, upon uncovering deficiencies in our models, our motivation is to seek solutions to correct the deficiencies. The important point is that LANL has produced constitutive models that have been characterized against simple loading states (uniaxial compression, tension, uniaxial strain, etc.), while this problem exercises them on complex loading states.

Figure 3 shows the result of one of the impact experiments. After the steel ball was fired at 708 m/s, the cover copper plates were stripped off and a section removed from the mock HE sample to reveal the penetration depth of the ball, as well as the damage that occurred during impact. A dye was used to highlight the regions of damage. It was observed that massive localized damage occurs in the form of a crater at the entrance point of the ball. A conical-shaped secondary damage surface associated with micro- and macro-crack formation was also observed, with the base of the cone lying on the mock HE surface having a radius several centimeters from the impact hole. The cone tip coincides with the final rest position of the ball. Beneath the ball the material was discolored, indicating compaction damage of the mock HE. Interestingly, the penetration hole was always plugged with solid mock HE material, indicating the material flowed back into the penetration hole. Closer to the bottom of the mock HE sample, conical damage was also observed. Finally, insignificant bulging of the bottom surface was observed.

Figure 3 also shows the results of one of our simulations done on the same geometry. The viscoelastic behavior of the mock HE is well captured in that our model successfully accounts for the material flowing over the trapped ball. Damage was also conical in shape but far more diffuse than what was observed in the experiment. Perhaps the biggest discrepancy was that our simulation showed significant bulging of the bottom of the mock HE. In the field of penetration the bulge is referred to as "plug formation," which is common in materials that have a weak shear strength but a strong compressive strength. It is clear that our HE model overestimates this effect and must be accordingly modified. Because the temperature rise in the simulation indicated substantial heating, the next step in the experiment will be to include thermal couples to verify the temperature rise.

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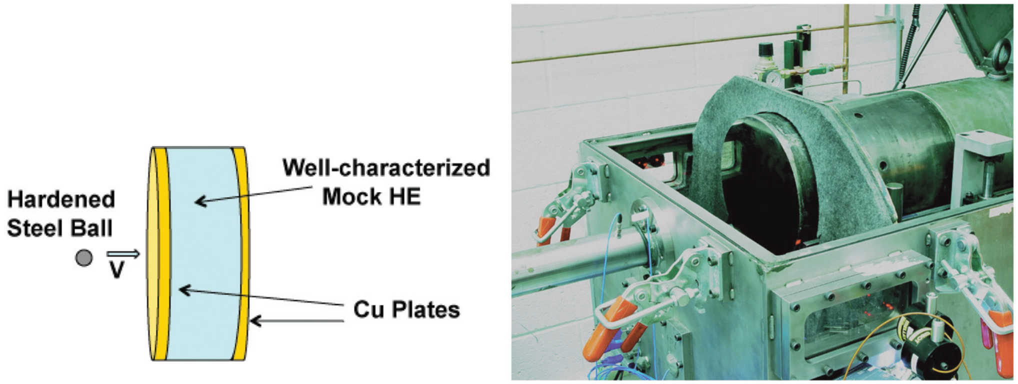

Fig. 1. Schematic of the experimental setup (left) and MST Taylor gun where the impact experiments are preformed (right).

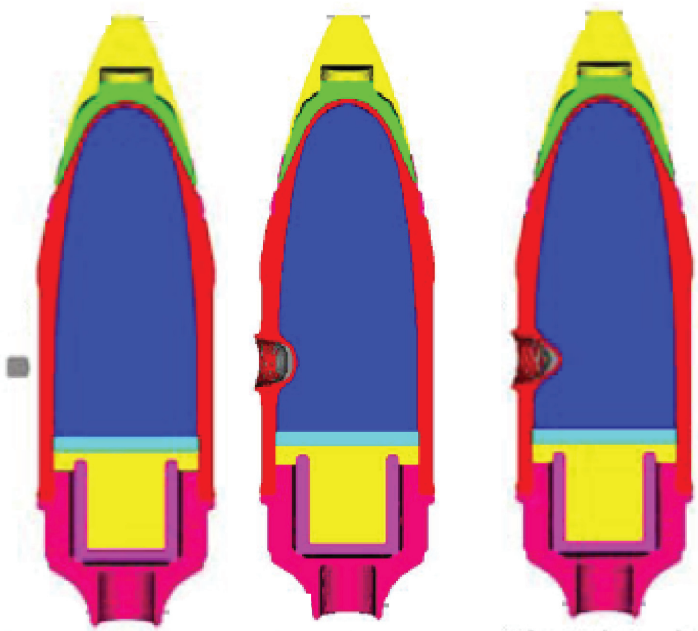

Fig. 2. Simulation of a munition impacted from the side by a hostile fragment. The simulation used a LANL-developed HE constitutive model.

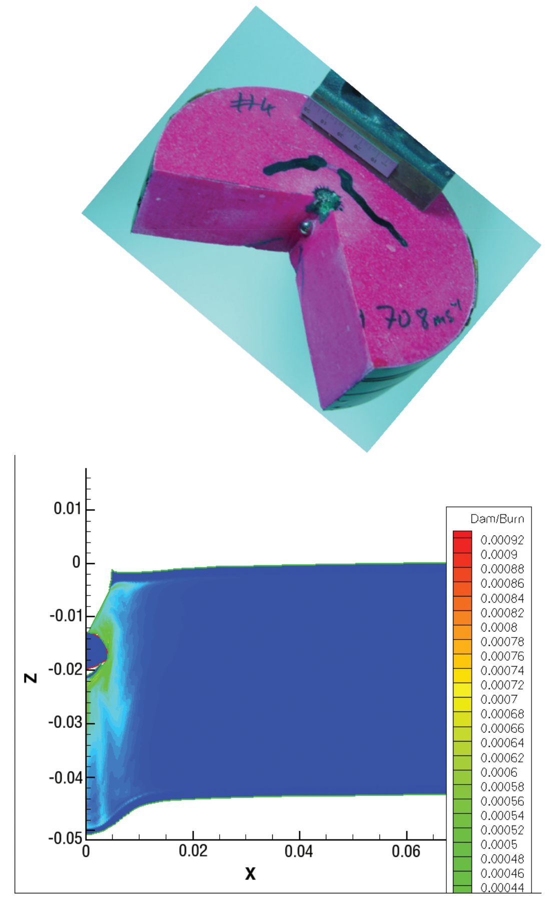

Fig. 3. Post-mortem study of the Taylor-fired ball into a mock HE (top), and the corresponding simulation using a LANL developed HE model (bottom).

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